Service-Oriented Networking Architecture

Bushar Yousef

A Thesis presented for the degree of Doctor of Philosophy

UNIVERSITY OF TECHNOLOGY SYDNEY

Department of Computer Science

Faculty of Information Technology

University of Technology Sydney

Australia

2009

Acknowledgements

Firstly, I would like to thank my supervisor, Prof. Doan Hoang, for his unwavering guidance and support. I am immensely grateful for the opportunity to work under his supervision and to be able to benefit from the wealth of his knowledge and experience. Without his invaluable input, constructive feedback, passion and enthusiasm, none of this would have been possible.

I would like to thank my co-supervisor, Glynn Rogers, for his valuable time, insight and encouragement along the way.

Those who are very close to me – my father, my mother, and my wife – thank you. Their support, patience and unrelenting faith gave me great strength to persevere with my ambition.

Finally, I would like to thank Chi, Hanh, Ming, Trung, and Joe. We started out as research group colleagues and became friends for life. It is a privilege to be affiliated with such a productive and collaborative team. Most importantly, I appreciate their exuberance and empathy which was needed during tough times. I would like to especially thank Trung for providing MIB wrappers which proved to be greatly helpful in the implementation of the System Services of *Serviter*.

Certificate of Authorship/Originality

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidate

Bushar Yousef

Abstract

Demand for new services offered across shared networking infrastructure, such as the Internet, is at an ever increasing level. Everyday, innovative services are continuously being proposed and developed to meet end users' demands. However, the monolithic and inflexible design of current networking infrastructure constrains the deployment of such new services. Current networking infrastructure consists of a fixed set of connectivity functions governed by static overlays of Service Level Agreements between administrative boundaries. This infrastructure hinders new service deployment to a slow process of standardisation and legal agreements, and requires large capital expenditure for the roll out of new network elements.

Service-Oriented Networking is a new paradigm aimed at transforming networking infrastructure to meet new demands in a responsive and inexpensive manner. It proposes enabling on-demand introduction of services across shared and heterogeneous networking infrastructure. However, architecting the building blocks of a feasible service-oriented network poses many critical research challenges.

The first challenge is in providing an architecture that enables on-demand injection and programmability of services. This architecture must not compromise current scalability and performance levels of networks. Furthermore, due to the heterogeneous nature of networks, this architecture must cater for a large number of platforms with varying capabilities.

The second challenge is in enforcing security among services of competing entities on leveraging shared infrastructure. With the possibility of faulty or malicious services being deployed, mechanisms are needed to impose isolation of risk to maintain a robust network. These mechanisms must scale to a large number of entities and should not impose restrictions on programmability that would limit the operations of services. Furthermore, this needs to be achieved without the introduction of checking operations in the path of network traffic which would impede the performance of the network.

The third challenge is in guaranteeing Quality of Service (QoS) levels across competing services in a differentiated and fair manner. Providing QoS guarantee would no longer be just a problem of bandwidth allocation but would now involve the allocation of computational resources needed in the fulfilment of a service. The critical issue is in formulating a resource allocation scheme among competing services where resource requirements or availability cannot be predetermined. Again, any mechanism used must be scalable for large numbers of services.

Recent research in the fields of Active and Programmable Networks has produced novel architectures which adopt user-extensible software components or programmable network processors to enable rapid service deployment. However, it is currently impractical to adopt such concepts as the associated challenges (outlined above) have only been partially addressed. Meanwhile, commercial platforms are becoming both faster and increasingly more programmable. However, commercial manufacturers have developed their platforms in a proprietary and closed manner, thereby restricting users from deploying new services or customising existing services.

This thesis explores a holistic approach to overcoming the challenges of Service-Oriented Networks. Specifically, it presents a new and novel architecture called ***Serviter***: *a new Service-Oriented Network Architecture for Shared Networks*. With this architecture, a new class of network elements enriched with programmable functionality can be deployed to serve as the fundamental building blocks of a new Service-Oriented Networking model. Under this model, service provisioning responsibilities are divided among manufacturers, network providers, and service providers. Manufacturers' responsibilities focus on the provisioning of increasingly programmable high-performance infrastructure and their system-level drivers. Network providers are responsible for the management of their infrastructure, which would be divided into isolated shares and opened to third party service providers. The service providers are then able to deploy new services within their shares of a domain. These services can then be aggregated across domains to provision end-to-end services through the purchase of dedicated shares, or a collaborative model, spanning the required paths.

Serviter enables on-demand service deployment onto commercial programmable platforms leveraging their high performance and scalability characteristics. These characteristics are maintained by enforcing the separation of the control and the forwarding planes. A programmability interface is provided through a layer of System Services. To cater for the heterogeneous nature of networks, the System Services layer is extensible. It enables each manufacturer to utilise a unified programmability approach to develop and deploy new System Services to exploit the functionality of their reprogrammable hardware. The programmability of the underlying modules is offered through a structured and flexible approach of Active Flow Manipulation (AFM) Paths. Users deploy User Services that construct AFM Paths to offer new network services.

Serviter introduces novel scalable and simple partitioning techniques to address the issues of network integrity and security. Serviter provides each service provider with a secure, separate, and resource assured partition, representing a 'Virtual Router', to accommodate their services. These partitions span all components and restrict services from constructing AFM Paths on traffic outside of the Virtual Networks associated with their partition.

To allocate internal router resources among competing partitions and among services within a partition, Serviter employs a scalable and autonomic resource management model called *Control plane-Quality of Service (C-QoS)*. Due to the difficulty of determining resource availability in heterogeneous infrastructure or service resource requirements, this model is dynamically adaptive to demand and availability patterns on a per resource basis.

To demonstrate the significance of the new architecture, this thesis presents an implementation of Serviter along with its deployment onto an advanced commercial networking platform. The implementation is assessed and evaluated for its ability to map on to commercial infrastructure, its partitioning enforcement, and its overall performance and scalability. This platform is used to implement novel services demonstrating Serviter capabilities. It is shown that Serviter is capable of facilitating on-demand deployment of a variety of services constrained by forward plane capabilities.

This architecture opens the opportunity for service-oriented networking in large-scale shared networks, putting forth new challenging issues in the complete automation of service deployment – specifically, capability discovery, location selection, and dynamic domain aggregation to provide end-to-end service construction.

Contents

List of Figures

List of Tables